Name _____ Class _____ Date _____

8 Covalent Bonding

Big idea BONDING, INTERACTIONS, AND NAMING COMPOUNDS

8.1 Molecular Compounds

For students using the Foundation edition, assign problems 1–11.

Essential Understanding Ionic and molecular compounds can both be represented by formulas, but contain different types of bonding and representative units.

Reading Strategy

Frayer Model The Frayer Model is a vocabulary development tool. The center of the diagram shows the concept being defined, while the quadrants around the concept are used for providing the details. Use this model when you want to understand a vocabulary term in more detail.

As you read Lesson 8.1, use the Frayer Model below to better understand the word *molecule*.

Definition in your own words	Facts/characteristics
group of atoms that bonds by sharing electrons and has no charge	*can be two of the same atom or atoms of different elements* *held together by covalent bonds*
molecule	
Examples	**Nonexamples**
H_2O, CO_2, O_2, NH_3	*NaCl, NaOH*

EXTENSION **Create a Frayer Model for each of the terms *covalent bond, diatomic molecule, molecular compound,* and *molecular formula*.**

Lesson Summary

Molecules and Molecular Compounds The electrons in a molecular compound are shared.

- The atoms in a molecular compound are held together by covalent bonds.
- Molecular compounds can be represented by molecular formulas, which tell how many of each type of atom are in the compound.

Name _____ Class _____ Date _____

Types of Molecular Compounds	
Diatomic	**More than one element**
H_2, O_2, N_2, Cl_2	H_2O, NH_3, C_2H_6O

Comparing Molecular and Ionic Compounds Unlike ionic compounds, molecular compounds have no charge and are held together by covalent bonds.

- The formula for a molecular compound describes the combination of atoms that make up one molecule.
- The formula for an ionic compound describes a ratio of ions in the compound.

After reading lesson 8.1, answer the following questions.

Molecules and Molecular Compounds

1. What is a covalent bond?

A covalent bond is a bond formed when two atoms share electrons.

2. Many elements found in nature exist as *molecules*.

3. What is a molecule?

A molecule is a neutral group of atoms joined together by covalent bonds.

4. Compounds that are formed when two or more atoms combine to form molecules are called *molecular compounds*.

5. Circle the letter of the substances that do NOT exist as molecules in nature.

a. oxygen
b. water
c. neon
d. ozone
e. helium

6. List two general properties of molecular compounds.

a. *low melting and boiling points*

b. *exist as gases or liquids at room temperature*

7. What is a molecular formula?

A molecular formula shows how many atoms of each element a molecule contains.

Match each compound with its molecular formula.

c **8.** carbon dioxide — **a.** C_2H_6O

a **9.** ethanol — **b.** NH_3

b **10.** ammonia — **c.** CO_2

Name _____ Class _____ Date _____

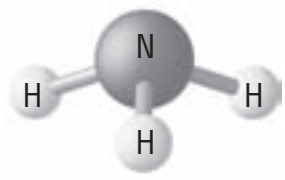
11. Is the following sentence true or false? A molecular formula shows the arrangement of the atoms in a molecule. ***false***

In the diagram, match the type of model or formula with its representation.

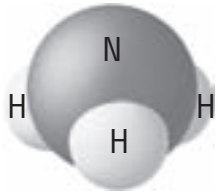
a. ball-and-stick drawing
b. molecular formula
c. perspective drawing
d. space-filling molecular model
e. structural formula

$NH_3(g)$

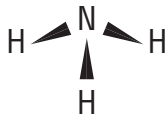
12. ***b***



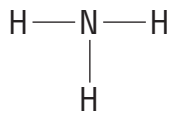
13. ***a***



14. ***d***



15. ***c***



16. ***e***

17. What term describes the arrangement of atoms within a molecule?

molecular structure

Comparing Molecular and Ionic Compounds

18. How do the formulas differ for molecular and ionic compounds?

The formula for a molecular compound represents the atoms that make up one molecule of the compound. The formula for an ionic compound represents one formula unit of the compound.

8.2 The Nature of Covalent Bonding

For students using the Foundation edition, assign problems 2, 4, 5, 8, 10, 11, 14.

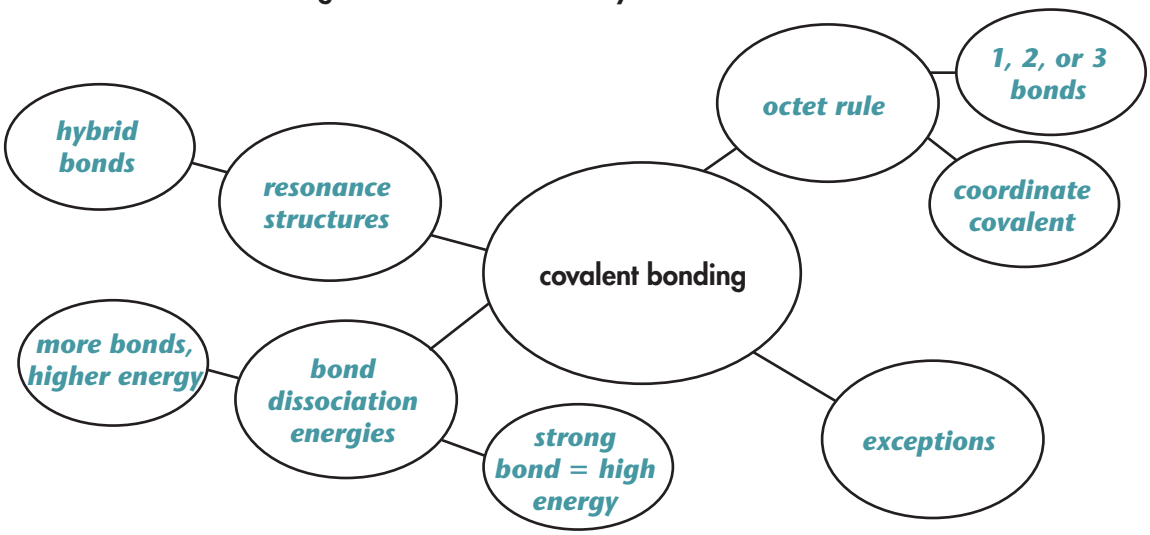
Essential Understanding Covalent bonds form when atoms share electrons.

Reading Strategy

Cluster Diagram Cluster diagrams help you know how concepts are related. Write the main idea or topic on a sheet of paper. Circle it. Draw lines branching off the main idea, connected to circles that contain concepts related to the main concept. Continue adding facts and details to the branches.

Name _____ Class _____ Date _____

As you read Lesson 8.2, use the cluster diagram below to show how each section of the lesson relates to covalent bonding. Add circles if necessary.



EXTENSION **Draw a cluster diagram for each type of bond.**

Lesson Summary

The Octet Rule in Covalent Bonding Covalent compounds are most stable when each atom has eight electrons.

- Single, double, and triple covalent bonds depend on the number of pairs of electrons shared between two atoms.
- Atoms form double or triple covalent bonds if they can attain a noble gas structure by doing so.

Type of Covalent Bond	Attributes
Single	**One** shared electron pair with **one** electron from each atom
Double	**Two** shared electron pairs with **two** electrons from each atom
Triple	**Three** shared electron pairs with **three** electrons from each atom

Coordinate Covalent Bonds In a coordinate covalent bond, one atom contributes both electrons in the bonding pair.

- One atom may contribute a pair of unshared electrons to a bond to give both atoms an inert gas configuration.
- Coordinate covalent bonds can also occur in polyatomic ions, such as NH_4^+.

Exceptions to the Octet Rule Some molecules have fewer, or more, than a complete octet of valence electrons.

- Molecules that have an odd number of total valence electrons cannot satisfy the octet rule.
- Some molecules that have an even number of valence electrons may also fail to follow the octet rule.

Name _____ Class _____ Date _____

Bond Dissociation Energies The energy needed to break a covalent bond depends on the strength of the bond.

- A large bond dissociation energy corresponds to a strong covalent bond.
- Double and triple bonds are stronger than single bonds.
- Reactivity is linked to the strength or weakness of the covalent bonds.

Resonance The bonding in some molecules is a blend of several valid electron dot structures.

- The possible electron dot structures are called resonance forms.
- Electron pairs do not move back and forth between resonance forms.

After reading Lesson 8.2, answer the following questions.

The Octet Rule in Covalent Bonding

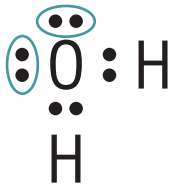
1. What usually happens to the electron configuration of an atom when it forms a covalent bond?

   The atom acquires the electron configuration of a noble gas.

2. Is the following sentence true or false? In a structural formula a shared pair of electrons is represented by two dashes. *false*

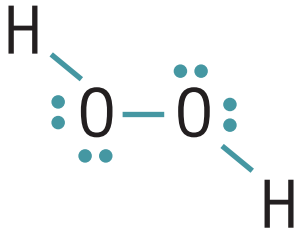
3. Structural formulas show the arrangement of *atoms* in molecules.

4. Use the electron dot structure below. Circle each unshared pair of electrons in a water molecule.

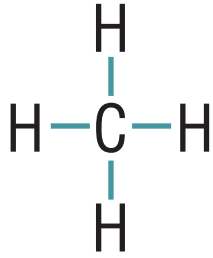


5. Complete the electron dot structure for each molecule. Each molecule contains only single covalent bonds.

a. NH_3



b. H_2O_2



c. CH_4

6. A chemical bond formed when atoms share two pairs of electrons is called a(n) *double covalent bond*.

Name _____ Class _____ Date _____

7. How many covalent bonds are in a nitrogen molecule?

three

8. Is the following sentence true or false? All diatomic molecules contain double bonds.
false

Coordinate Covalent Bonds

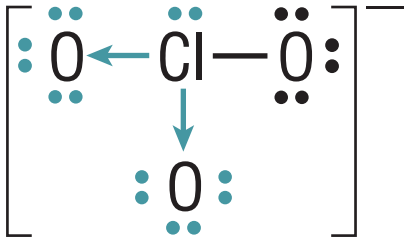
9. What is a coordinate covalent bond?

It is a covalent bond in which one atom contributes both bonding electrons.

10. Look at Table 8.2. Which nitrogen compounds contain coordinate covalent bonds?

nitrogen dioxide, dinitrogen tetroxide, and nitrous oxide

11. Complete the electron dot structure for the chlorate ion (ClO_3^-) by filling in the bonds and unpaired electrons.



Exceptions to the Octet Rule

12. Why does the NO_2 molecule not follow the octet rule?

There is an unpaired electron present in both possible resonance structures.

Bond Dissociation Energies

13. What is bond dissociation energy?

Bond dissociation energy is the energy required to break the bond between two covalently bonded atoms.

14. Is the following sentence true or false? Molecules with high bond dissociation energies are relatively unreactive. *true*

15. What is the bond dissociation energy for a typical C — C covalent bond?

347 kJ/mol

Resonance

16. The actual bonding in ozone is a *hybrid* of the extremes represented by its *resonance forms*.

Name _____ Class _____ Date _____

17. When can resonance structures be written for a molecule?

when it is possible to write two or more valid electron dot structures for the molecule that have the same number of electron pairs

8.3 Bonding Theories

For students using the Foundation edition, assign problems 2–8.

Essential Understanding Scientists use a variety of theories and models to explain how and why covalent bonds form.

Lesson Summary

Molecular Orbitals One model of molecular bonding pictures a molecular orbital that is a combination of individual atomic orbitals.

- A bonding orbital can be occupied by a pair of electrons.
- In a sigma (σ) bond, the molecular orbital is symmetrical around the axis connecting two atomic nuclei.
- In a pi (π) bond, the orbitals are sausage-shaped regions above and below the bond axis.

VSEPR Theory The VSEPR theory explains the shape of molecules in three-dimensional space.

- The acronym VSEPR stands for valence-shell electron-pair repulsion theory.
- This model assumes that electron pairs repel each other as far as possible.
- Unshared pairs of electrons also affect the shape of the molecules.

Hybrid Orbitals Orbital hybridization describes how orbitals from different energy levels combine to make equivalent hybrid orbitals.

- Information about the kind and shape of the bonds is explained by hybridization.
- Hybrid orbitals can form with single, double, or triple covalent bonds.

After reading Lesson 8.3, answer the following questions.

Molecular Orbitals

1. What is a molecular orbital?

When two atoms combine, their atomic orbitals overlap to produce orbitals that apply to the entire molecule.

2. Is the following sentence true or false? Electrons first fill the antibonding molecular orbital to produce a stable covalent bond. *false*

3. When two *s* atomic orbitals combine and form a molecular orbital, the bond that forms is called a(n) *sigma* bond.

4. Circle the letter of each type of covalent bond that can be formed when *p* atomic orbitals overlap.

(a.) pi **b.** beta (c.) sigma **d.** alpha

Name _____ Class _____ Date _____

VSEPR Theory

5. What is VSEPR theory?

The valence-shell electron-pair repulsion theory states that because electron pairs repel, molecular shape adjusts so the valence-electron pairs are as far apart as possible.

6. When the central atom of a molecule has unshared electrons, the bond angles will be *smaller* than when all the central atom's electrons are shared.

7. What is the bond angle in carbon dioxide? Why?

The bond angle is 180° because the carbon atom has no unshared electron pairs.

8. What are the names of these common molecular shapes?

linear

pyramidal

bent

trigonal planar

tetrahedral

trigonal bipyramid

Hybrid Orbitals

9. Is the following sentence true or false? Orbital hybridization theory can describe both the shape and bonding of molecules. *true*

10. What is orbital hybridization?

Orbital hybridization occurs when several atomic orbitals mix to form the same total number of equivalent hybrid orbitals.

Match the hybrid orbitals formed by carbon with the carbon compound in which they are found.

c	**11.** sp^3	**a.** ethyne
b	**12.** sp^2	**b.** ethene
a	**13.** sp	**c.** methane

Name _____ Class _____ Date _____

8.4 Polar Bonds and Molecules

For students using the Foundation edition, assign problems 1–7, 9–15, 17, 18, 20.

Essential Understanding A chemical bond's character is related to each atom's attraction for the electrons in the bond.

Lesson Summary

Bond Polarity In a polar covalent bond, the electrons are shared unequally.

- A difference in electronegativity causes a molecule to have a slightly positive and a slightly negative end.

Attractions Between Molecules Several different forces cause attraction between molecules.

- If polar bonds within a molecule cancel out, the molecule itself is nonpolar.
- Dipole interactions occur between polar molecules.
- Moving electrons cause weak attractions called dispersion forces.
- A hydrogen bond is a strong dipole interaction between water and another molecule.

Intermolecular Attractions and Molecular Properties Varying intermolecular attractions cause a diversity of physical properties in covalent compounds.

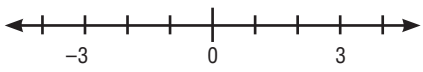
- Molecular compounds have lower melting and boiling points than ionic compounds.
- A solid in which all atoms are covalently bonded is a very stable substance called a network solid.

BUILD Math Skills

Absolute Value The absolute value of an integer is its numerical value without regard to whether the sign is negative or positive.

The symbol for absolute value is to enclose the number between vertical bars such as $|-3| = 3$, and is read "*the absolute value of negative 3 is 3.*"

On a number line the absolute value is the distance between the number and zero.



Both 3 and −3 are a *distance* of 3 units from 0. $|3| = |-3| = 3$. Distance, in mathematics, is never negative. This is why absolute value is never negative; absolute value only asks *how far?* not *in which direction?* This means not only that $|3| = 3$, because 3 is three units to the right of zero, but also that $|-3| = 3$, because −3 is three units to the left of zero.

Name _____ Class _____ Date _____

Sample Problem Simplify $-|-3|$.

First, simplify $|-3|$. → $-|-3| = -|3|$

Now remove the absolute value bars. → $-|-3| = -3$

Hint: Remember that the absolute-value notation is bars, not parentheses or brackets. Use the proper notation; the other notations do not mean the same thing.

Sample Problem Simplify $|2 + 3(-4)|$.

Follow the order of operations. First, multiply 3×-4. → $|2 + 3(-4)| = |2 - 12|$

Now subtract. → $|2 + 3(-4)| = |2 - 12| = |-10|$

Finally, remove the absolute value bars. → $|2 + 3(-4)| = |2 - 12| = |-10| = 10$

Now it's your turn to practice simplifying absolute values. Remember to do the order of operations in the correct sequence.

1. Simplify $1 - |-1|$.

$1 - 1 = 0$

2. Simplify $|0 - 6|$.

$|0 - 6| = |-6| = 6$

3. Simplify $|8| + |-4|$.

$8 + 4 = 12$

4. Simplify $-|(-2)^2|$.

$-|(-2)^2| = -|4| = -4$

5. Simplify $\frac{-4}{|-4|}$.

-1

6. Simplify $-8 + |-7|$.

$-8 + 7 = -1$

After reading Lesson 8.4, answer the following questions.

Bond Polarity

7. Describe how electrons are shared in each type of bond. Write *equally* or *unequally*.

a. Nonpolar bond *equally* **b.** Polar bond *unequally*

8. Why does the chlorine atom in hydrogen chloride acquire a slightly negative charge?

Chlorine has a higher electronegativity value than hydrogen, and, therefore, attracts the electron cloud more than hydrogen.

Name _____ Class _____ Date _____

9. What symbols are used to represent the charges on atoms in a polar covalent bond? The polarity of the bond? *δ+ and δ− ; →* _____

Match the electronegativity difference range with the type of bond that will form.

b **10.** 0.0–0.4

d **11.** 0.4–1.0

c **12.** 1.0–2.0

a **13.** > 2.0

a. ionic

b. nonpolar covalent

c. very polar covalent

d. moderately polar covalent

14. Circle the letter of each sentence that is true about polar molecules.

(a.) Some regions of a polar molecule are slightly negative and some are slightly positive.

b. A molecule containing a polar bond is always polar.

(c.) A molecule that has two poles is called a dipolar molecule.

(d.) When polar molecules are placed in an electric field, they all line up with the same orientation in relation to the charged plates.

15. Are the following molecules polar or nonpolar?

a. H_2O *polar*

b. CO_2 *nonpolar*

c. NH_3 *polar*

d. HCl *polar*

Attraction Between Molecules

16. What causes dispersion forces?

Dispersion forces are caused by the motion of electrons.

17. Is the following sentence true or false? Dispersion forces generally increase in strength as the number of electrons in a molecule increases. *true*

18. The strongest of the intermolecular forces are *hydrogen bonds*.

Intermolecular Attractions and Molecular Properties

19. What determines the physical properties of a compound?

The physical properties depend on the type of bonding in the compound and intermolecular attractions.

20. Use Table 8.5 on page 245 to complete the following table.

Characteristic	Ionic Compound	Covalent Compound
Representative unit	*formula unit*	*molecule*
Physical state	*solid*	*solid, liquid, or gas*
Melting point	*high*	*low*
Solubility in water	*usually high*	*high to low*

Name _____ Class _____ Date _____

Guided Practice Problem

Answer the following questions about Practice Problem 30.

Identify the bonds between atoms of each pair of elements as nonpolar covalent, moderately polar covalent, very polar covalent, or ionic.

a. H and Br **c.** C and O **e.** Li and O

b. K and Cl **d.** Cl and F **f.** Br and Br

Analyze

Step 1. What is the most probable type of bond for each electronegativity difference range?

Electronegativity Difference Range	Most Probable Type of Bond
0.0–0.4	*nonpolar covalent*
0.4–1.0	*moderately polar covalent*
1.0–2.0	*very polar covalent*
≥ 2.0	*ionic*

Solve

Step 2. From Table 6.2, determine the electronegativity values and differences for each pair of elements.

a. H = 2.1, Br = [*2.8*]; [*0.7*]

b. K = [*0.8*], Cl = 3.0; [*2.2*]

c. C = [*2.5*], O = 3.5; [*1*]

d. Cl = 3.0, F = [*4.0*]; [*1*]

e. Li = [*1.0*], O = 3.5; [*2.5*]

f. Br = 2.8, Br = [*2.8*]; [*0*]

Step 3. Refer to Table 8.3 to determine the most probable type of bond for each compound.

a. *moderately polar covalent*

b. *ionic*

c. *very polar covalent*

d. *very polar covalent*

e. *ionic*

f. *nonpolar covalent*

Apply the Big idea

Fill in the chart for each compound.

	C_2H_4	N_2	CCl_4
type of bond	*C–C triple bond*	*N–N triple bond*	*C–Cl single bonds*
dot diagram	H:C⋮⋮C:H	:N⋮⋮⋮N:	Cl, Cl : C : Cl, Cl
3-D structure	*linear*	*linear*	*tetrahedral*
type of bond based on polarity	*nonpolar*	*nonpolar*	*nonpolar*
high or low boiling point	*low*	*low*	*higher than the others*

Name _____ Class _____ Date _____

8 Self-Check Activity

For Questions 1–12, complete each statement by writing the correct word or words. If you need help, you can go online.

8.1 Molecular Compounds

1. The number of ***atoms*** of each element is shown in the molecular formula.

2. A ***molecule*** is the representative unit of a molecular compound, while for an ionic compound, it is a ***formula unit***.

8.2 The Nature of Covalent Bonding

3. In covalent bonds, electrons are shared in such a way that the configuration is the same as a ***noble gas***.

4. A single atom provides the shared electron pair in a ***coordinate*** covalent bond.

5. A ***strong*** covalent bond has a large bond dissociation energy.

6. The resonance forms of ozone show the extremes that make up the ***hybrid*** bonding of oxygen atoms.

8.3 Bonding Theories

7. A ***molecular*** orbital is one that belongs to a molecule as a whole.

8. The ***VSEPR*** theory is used by scientists to explain the three-dimensional shape of molecules.

9. Information about both molecular bonding and molecular shape is provided by ***orbital hybridization***.

8.4 Polar Bonds and Molecules

10. A slightly negative charge is found on the more ***electronegative*** atom when two atoms bond.

11. Ionic and covalent bonds are both ***stronger*** than intermolecular attractions.

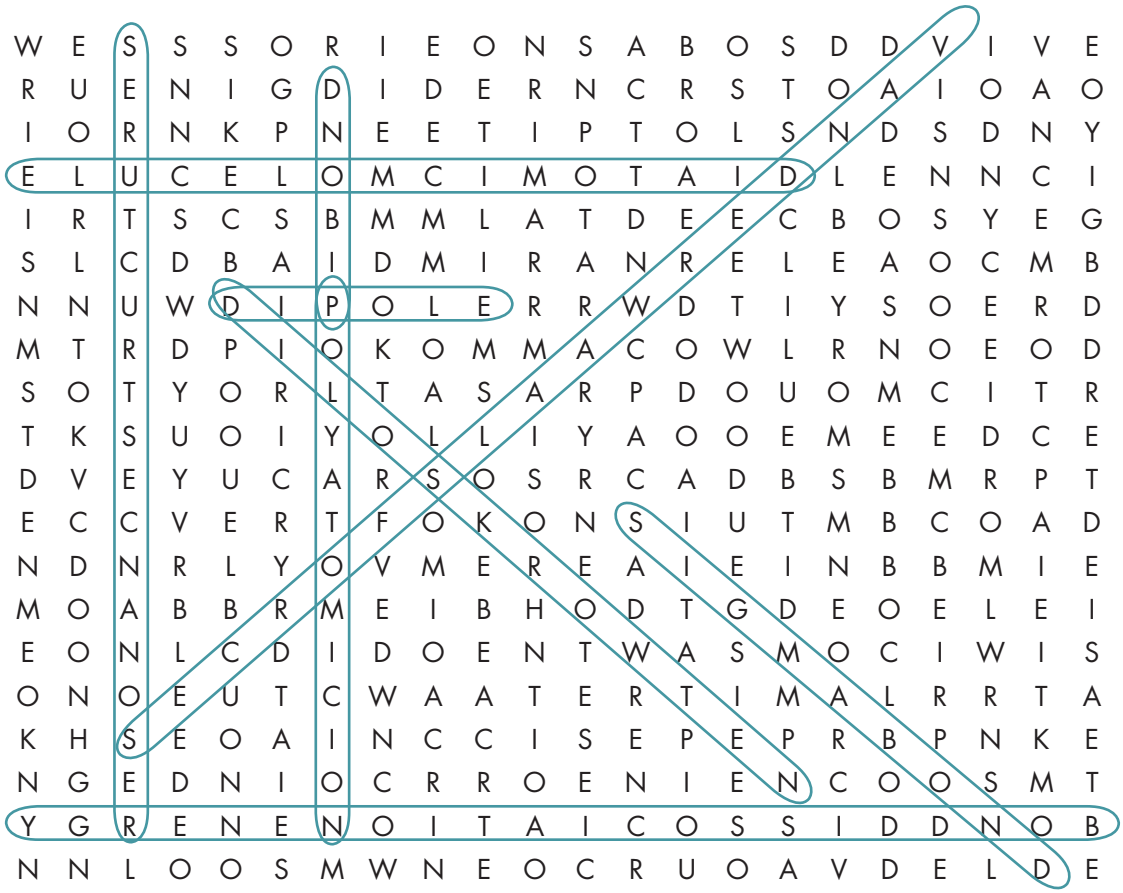
12. The variance in ***intermolecular*** attractions explains the diversity of physical properties among covalent compounds.

If You Have Trouble With…												
Question	1	2	3	4	5	6	7	8	9	10	11	12
See Page	215	216	218	224	228	229	232	234	236	240	242	244

Name _____ Class _____ Date _____

Review Vocabulary

Use the clues to find the vocabulary words hidden in the puzzle. Then circle the words. The terms may be appear horizonatally, vertically, or diagonally.



Clues

1. name given to a group of weak intermolecular attractions
2. a substance with a high melting point in which all the atoms are covalently bonded
3. two or more valid electron dot structures with the same number of electron pairs for the same molecule or ion
4. a group of tightly bound atoms that act as a group with either a positive or negative overall charge
5. F_2 and O_2 are examples
6. the energy required to break the bond between two covalently bonded atoms
7. electrons are found in dumbbell-shaped regions above and below the axis of the bonding atoms
8. when electrons are found in an orbital that is symmetrical around the axis of the bonded atoms
9. a molecule that has two poles

Hidden Words

van der Waals forces

network solid

resonance structures

polyatomic ion

diatomic molecule

bond dissociation energy

pi bond

sigma bond

dipole